A SELECTION MODULE FOR AN OPTICAL SIGNAL SWITCH AND AN OPTICAL SIGNAL SWITCH

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is based on French Patent Application No. 03 02 603 filed March 4, 2003, the disclosure of which is hereby incorporated by reference thereto in its entirety, and the priority of which is hereby claimed under 35 U.S.C. §119.

BACKGROUND OF THE INVENTION

Field of the invention

The present invention relates to a selection module for an optical signal switch.

Description of the prior art

Telecommunications is expanding greatly. More and more users (private persons and companies) are transmitting over telecommunication networks more and more messages containing more and more information, for example when sending pictures. To satisfy this growing information bit rate demand, telecommunication network operators are adopting optical signal transmission involving modulation of optical signals, generally produced by lasers, in accordance with the information to be transmitted, followed by propagation of the modulated signals over a network of optical waveguides or optical fibers.

Optical signal transmission has a number of advantages. In particular, optical signals are attenuated less during transmission than electrical signals and optical fibers are mechanically stronger and lighter than their electrical counterparts. However, the main advantages are the high bandwidth of optical fibers and the ability to transmit a plurality of carriers with different wavelengths simultaneously in the same fiber. This latter technique, known as wavelength division multiplexing, provides information bit rates of the order of 1 gigabit/s and even 1 terabit/s.

In parallel with wavelength division multiplexing, time division multiplexing enables the simultaneous transmission of a plurality of calls on the same carrier because each carrier transmits packets relating to different messages whose information content has been divided between the packets, which are sent over the network with a header indicating their destination. When the packet passes through a switch, the latter locks its

signal F_t (t varying from 1 to L).

The signal F_t is a WDM signal comprising C_e channels associated with respective different wavelengths belonging to a predefined WDM comb.

Each of the signals F_t is amplified by the amplifier A_t, which is an erbium-doped fiber amplifier, for example, and is then broadcast by one of the L couplers D_1 to D_L to a corresponding input of each of the $C_x \times P_s$ selection modules S_1 to $S_{C_{s_x}P_s}$, each selection module having L inputs and one output.

Figure 2 shows a selection module S used in the switch shown in figure 1.

The selection module S comprises:

- a spatial selector SE_1, and

- a spectral selector SE_2.

The spatial selector SE_1 comprises:

- L optical ports G_t (t varying from 1 to L) having inputs that constitute L respective inputs of the spatial selector SE_1, and

- an optical coupler $C_{L:1}$ for selectively coupling the L inputs via optical gates to a single output that constitutes the output of the spatial selector.

Each optical gate (optical switch) G_t is typically a semiconductor optical amplifier that is supplied with power only when it must transmit a signal.

Each of the L inputs receives a WDM signal F_t which therefore comprises a plurality of channels each associated with a wavelength.

Thus the spatial selector SE_1 sends to its output only one of the L signals F_t it has received.

The spectral selector SE_2 selects only one of the plurality of channels of the signal F_t selected by the spatial selector SE_1.

The spectral selector SE_2 has a tunable filter function. It may comprise, for example:

- a demultiplexer comprising an input receiving the signal selected by the spatial selector and a plurality of outputs,

- a multiplexer comprising a plurality of inputs and an output supplying the signal associated with the channel selected from the plurality of channels of the signal selected by the spatial selector, and

signal F_t (t varying from 1 to L).

The signal F_t is a WDM signal comprising C_e channels associated with respective different wavelengths belonging to a predefined WDM comb.

Each of the signals F_t is amplified by the amplifier A_t, which is an erbium-doped fiber amplifier, for example, and is then broadcast by one of the L couplers D_1 to D_L to a corresponding input of each of the $C_x \times P_s$ selection modules S_1 to $S_{Cs_x Ps}$, each selection module having L inputs and one output.

Figure 2 shows a selection module S used in the switch shown in figure 1.

The selection module S comprises:

- a spatial selector SE_1, and
- a spectral selector SE_2.

The spatial selector SE_1 comprises:

- L optical ports G_t (t varying from 1 to L) having inputs that constitute L respective inputs of the spatial selector SE_1, and
- an optical coupler $C_{L:1}$ for selectively coupling the L inputs via optical gates to a single output that constitutes the output of the spatial selector.

Each optical gate (optical switch) G_t is typically a semiconductor optical amplifier that is supplied with power only when it must transmit a signal.

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Thus the spatial selector SE_1 sends to its output only one of the L signals F_t it has received.

The spectral selector SE_2 selects only one of the plurality of channels of the signal F_t selected by the spatial selector SE_1.

The spectral selector SE_2 has a tunable filter function. It may comprise, for example:

- a demultiplexer comprising an input receiving the signal selected by the spatial selector and a plurality of outputs,
- a multiplexer comprising a plurality of inputs and an output supplying the signal associated with the channel selected from the plurality of channels of the signal selected by the spatial selector, and

- a plurality of optical switches such as semiconductor optical amplifiers each having an input connected to an output of the demultiplexer and an output connected to an input of the multiplexer.

Referring to figure 1, each of the Cs×Ps selection modules S_1 to $S_{Cs \times Ps}$ selects a particular signal F_t and extracts therefrom a particular channel that is sent to one of the Cs×Ps optical regenerators RO_k.

The channels intended for an output fiber O_m (m varying from 1 to P_s) are first multiplexed by one of the P_s multiplexers MO_1 to MO_{Ps} each having C_s inputs and an output connected to one of the P_s output ports.

Certain problems are encountered with a switch of the above kind, however.

The switch implies a large number of optical gates for implementing the selection modules. Each of the Cs×Ps output gates ahead of multiplexing toward the output fibers implies a selection module, and thus a spatial selector and a spectral selector for selecting a channel, both these selectors comprising a large number of optical switches. This large number of optical switches implies not only high cost but also high power consumption and a large overall size of the switch.

The present invention aims to provide a selection module for switching optical signals whereby the number of optical gates used in said switch can be reduced and the overall power consumption and the overall size of the switch reduced accordingly.

SUMMARY OF THE INVENTION

To this end the invention proposes a selection module for use in an optical signal switch, the module comprising a spatial selector comprising a plurality of inputs each receiving a wavelength division multiplexed optical signal comprising a plurality of channels each associated with a separate wavelength, an output delivering a single signal selected from the plurality of wavelength division multiplexed signals, and a plurality of spectral selectors each selecting a channel from a plurality of channels of the signal selected by the spatial selector.

The invention exploits the fact that a plurality of optical packets during the same time interval on a given input optical fiber can be addressed to the same output fiber. The module according to the invention selects a plurality of channels, each corresponding to an optical packet,

addressed to the same output fiber at the same time. A plurality of spectral selectors therefore share the same spatial selector; this sharing saves a large number of optical gates (see below).

The selection module of the invention advantageously further comprises a first optical coupler having an input connected to the output of the spatial selector and a plurality of outputs each connected to an input of one of the spectral selectors.

The spatial selector advantageously comprises a second optical coupler having a number of inputs equal to the number of inputs of the spatial selector and one output, and a plurality of optical switches each associated with one of the inputs of the optical coupler and each having an input that constitutes an input of the spatial selector and an output coupled to the associated input of the second optical coupler.

The optical switches of the spatial selector are advantageously semiconductor optical amplifiers.

Each of the spectral selectors advantageously comprises a demultiplexer comprising an input receiving the signal selected by the spatial selector and a plurality of outputs, a multiplexer comprising a plurality of inputs and an output supplying the signal associated with a channel selected from a plurality of channels of the signal selected by the space selector, and a plurality of optical switches each comprising an input connected to an output of the demultiplexer and an output connected to an input of the multiplexer.

The optical switches of the spectral selector are advantageously semiconductor optical amplifiers.

The selection module of the invention advantageously further comprises an optical amplifier for amplifying the signal selected by the spatial selector and having an input connected to the output of the spatial selector.

The present invention also provides an optical signal switch adapted to receive a plurality of wavelength division multiplex input signals and comprising output ports supplying wavelength division multiplexed output signals each comprising a plurality of channels each associated with one wavelength, each of the input signals comprising a plurality of channels each associated with one wavelength, and the switch comprising a

broadcast stage comprising optical couplers associated with respective input signals, each optical coupler receiving at its input the associated input signal and broadcasting the signal toward a plurality of output ports, and a selection stage comprising a plurality of outputs, and a plurality of selection modules each having L inputs, the plurality of selection modules comprising means for selecting at one of the outputs one of the channels associated with one of the broadcast input signals, in which switch the selection stage comprises at least one selection module according to the invention.

The at least one selection module advantageously comprises n outputs each assigned to selecting one channel from a plurality of channels of the signal selected by the spatial selector, where n is an integer greater than 1 and less than Ce/Ps + 1.

Thus it can be shown that there is always one set of n channels of the same input signal that will be addressed to the same output fiber, n being less than $C_e/P_s + 1$. The n channels can therefore share the same spatial selector.

It is particularly advantageous if each of the P_s output ports is associated with u_k modules each comprising k outputs each selecting one channel from a plurality of channels of the signal selected by the spatial selector, C_e being an integer multiple of P_s greater than 1, k varying from 1 to C_e/P_s, and u_k being defined by the equation:

$$u_k = E\left(\frac{C_s - v_k - L.(k-1)}{k}\right) + (C_s - v_k - L.(k-1))\text{modulo}[k]$$

$$\text{where } v_k = v_{k+1} + k.u_k \text{ and } v_{\frac{Ce}{Ps}} = 0,$$

the operator E() designating the integer part function and the u_k modules being modules according to the invention for k varying from 2 to C_e/P_s.

Accordingly, for a given output fiber, there exists, among all the input ports of the switch associated with the input fibers, at least u_k sets of k channels of the same input signal multiplexed and addressed to that given output fiber. In other words, instead of the Cs×Ps selectors of the switch

shown in figure 1, there is a number of spatial selectors equal to $\left(\sum_{k=1}^{\frac{Ce}{Ps}} u_k\right).P_S$.

The switch advantageously comprises P_s multiplexers each having C_s inputs and one output connected to one of said P_s output ports.

Other features and advantages of the present invention will become apparent in the course of the following description of one embodiment, which is provided by way of illustrative and nonlimiting example.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 depicts a prior art optical switch.

Figure 2 depicts a prior art optical switch selection module.

Figure 3 depicts an optical switch selection module of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Figures 1 and 2 have been described already with reference to the prior art.

Figure 3 depicts a selection module M_k according to the invention.

The module M_k comprises:

- a spatial selector SE_1,
- an amplifier A_2,
- a coupler $C_{1:k}$, and
- k spectral selectors SE_{21} to SE_{2k}.

The spatial selector SE_1 comprises:

- L inputs each connected to an optical gate G_t (t varying from 1 to L), and
- an optical coupler $C_{L:1}$ for connecting L inputs to one output.

Each optical gate G_t is an optical switch such as a semiconductor optical amplifier activated only when it must transmit a signal.

Each of the L inputs receives a WDM signal comprising a plurality of channels each associated with a wavelength.

Thus the spatial selector SE_1 sends to its output only one of the L signals received.

The spatially selected signal is then amplified by the amplifier A_2 and then broadcast to the spectral selectors SE_{21} to SE_{2k} via the coupler $C_{1:k}$.

The coupler $C_{1:k}$ has an input connected to the output of the spatial

selector and k outputs each connected to an input of one of said spectral selectors SE_{21} to SE_{2k}.

Each of the spectral selectors SE_{21} to SE_{2k} selects one of the plurality of channels of the signal selected by the spatial selector SE_1.

The module M_k therefore spatially selects a WDM signal from the L WDM signals and then extracts from the spatially selected signal k channels each corresponding to a different wavelength.

Each of the spectral selectors SE_{21} to SE_{2k} may comprise, for example:

- a demultiplexer having an input receiving the signal selected by the spatial selector and a plurality of outputs,
- a multiplexer having a plurality of inputs and an output supplying the signal associated with the channel selected from the plurality of channels of the signal selected by the spatial selector, and
- a plurality of optical switches such as semiconductor optical amplifiers each having an input connected to an output of the demultiplexer and an output connected to an input of the multiplexer.

These modules M_k can advantageously be used in an optical switch of the type depicted in figure 1.

This is because it can be shown that there is always a set of n channels belonging to the same input signal to be addressed to the same output fiber, where the value of n is less than $C_e/P_s + 1$. The n channels can therefore share the same spatial selector.

To be more precise, for a given output fiber, there exist, among all the input ports of the switch associated with the input fibers, at least u_k sets of k channels coming from the same input port and addressed to the given output fiber, where u_k is defined by the following equation:

$$u_k = E\left(\frac{C_s - v_k - L.(k-1)}{k}\right) + (C_s - v_k - L.(k-1))\text{modulo}[k]$$

$$\text{where } v_k = v_{k+1} + k.u_k \text{ and } v_{\frac{Ce}{Ps}} = 0,$$

with k varying from 1 to C_e/P_s.

Each of the P_s output ports can be associated with u_k selection modules M_k (k varying from 1 to C_e/P_s) i.e. the total number of modules per

output port is equal to $\left(\sum_{k=1}^{\frac{Ce}{Ps}} u_k\right)$.

The module M_1 designates a prior art selection module such as the module S shown in figure 2.

In a switch comprising selection modules according to the invention, instead of the $Cs \times Ps$ spatial selectors of the switch depicted in figure 1, the number of spatial selectors is therefore equal to $\left(\sum_{k=1}^{\frac{Ce}{Ps}} u_k\right) . P_S$.

Consider a numerical example of the above proposal where $P_e=L=P_s=8$ and $C_e=C_s=32$; this example therefore relates to an optical switch having eight WDM input fibers and eight WDM output fibers. Each of the input and output fibers carries 32 channels and all the channels are modulated at 10 Gbit/s, so that the total capacity of the switch is 2.56 Tbit/s.

In this case, applying the equation for u_k yields:

$u_4=2$, $u_3=4$, $u_2=2$ and $u_1=8$.

There are therefore two modules M_4, four modules M_3, and two modules M_2 for each output optical fiber, the other eight selection modules M1 being prior art modules. There are 128 selection modules for all the output fibers, whereas the switch depicted in figure 1 would have 256 selection modules.

Thus 128 spatial selectors have been saved; each of the spatial selectors comprising eight optical switches, for example, the number of optical gates has therefore been reduced by 1 024.

Of course, the invention is not limited to the embodiment that has just been described.

In particular, the semiconductor optical amplifiers used in the spectral and spatial selectors can be replaced by any type of optical switch.